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LOCKHEED MISSILES AND SPACE CO INC PALO ALTO CA
NUMERICAL TECHNIQUES FOR HIGH INCIDENCE REENTRY
SEP 82 R WHITEHEAD, R CONTI

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NUMERICAL TECHNIQUES FOR HIGH INCIDENCE REENTRY AERODYNAMICS

FIRST QUARTERLY PROGRESS REPORT

September 22, 1982

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Contract Number: N00014-82-C-0690
Sponsor: Office of Naval Research
Period of Performance: 6-24-82 through 6-23-83
Technical Monitor: R. Whitehead (202) 696-4404
Project Leader: R. Conti (415) 858-4036

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PROGRESS DURING THE REPORTING PERIOD

The investigation of reentry flowfields at very high incidence conducted under the previous contract (N00014 -81-C-0380) showed that the Lockheed Navier-Stokes computer code is capable of producing accurate flowfield solutions at angles of attack up to about 50 degrees (see the Interim Technical Report for that contract, document LMSC D876839). The overall objectives of this project are to investigate the limits of applicability of the present techniques and to extend those limits in order to cover the full range of incidence encountered by the reentry vehicles of the Fleet Ballistic Missile (FBM) System.)

All the research we have conducted so far indicates that the aforementioned limit in angle of attack is created by the lack of proper modeling of the base flow, which develops strong communication with the windward side at high incidence, when the flow there becomes subsonic. Therefore, the effort to extend the limits of applicability of the numerical techniques should focus on better modeling of the base flow. To this effect, the activities during the first quarter consisted of numerical simulation of base flow.

The first step is to achieve accurate simulation of axisymmetric base flows. For this purpose, an axisymmetric version of the Navier-Stokes code was modified for application to the base region. This involved modification of the computational space and the boundary conditions applied to its edges, and development of a suitable computational mesh. The code was subsequently used to simulate one of the experiments reported by Blankson and Finston (1975). This experiment was selected as a test case because it was performed with a model suspended magnetically in a wind tunnel, thus eliminating the support interference effects that are known to affect the characteristics of the base flow. Several adjustments of the

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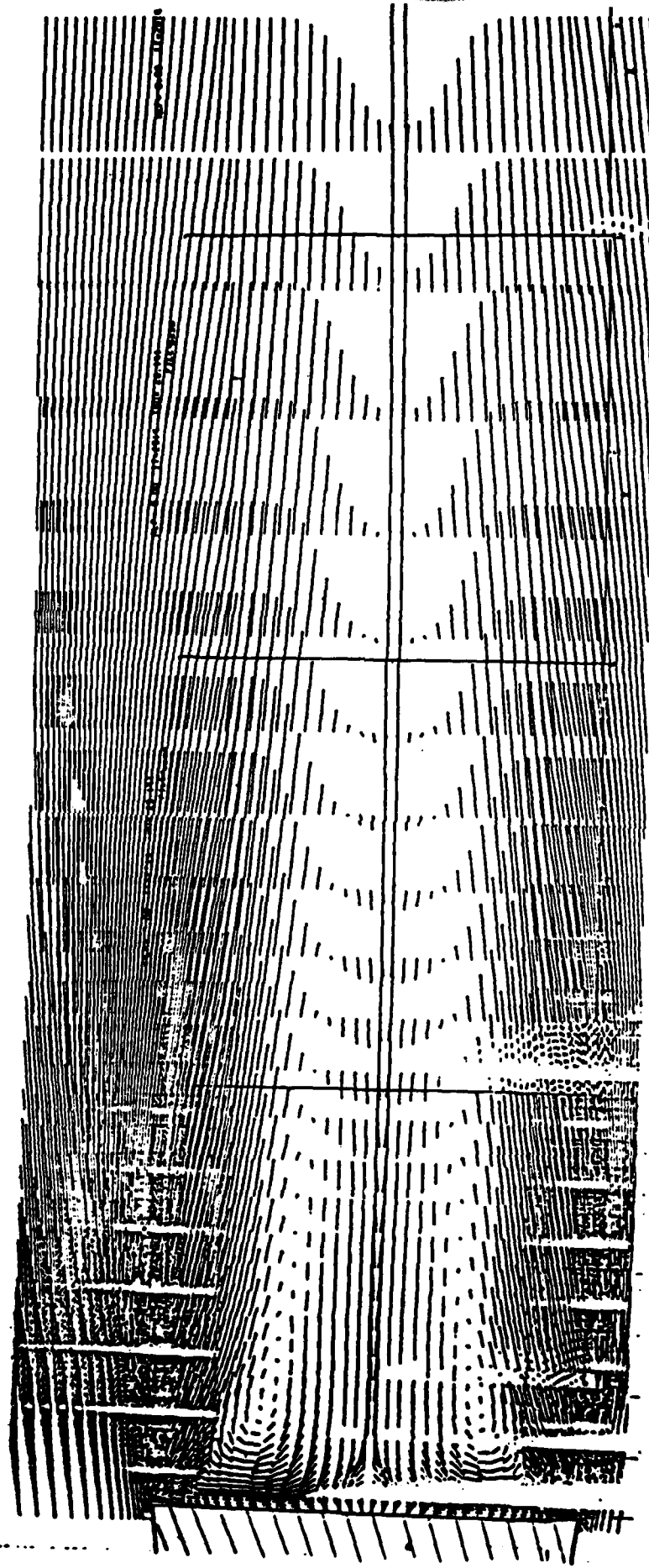
computational mesh and total number of nodes were needed before the simulation of this complex flow started to converge, when marched in time from an arbitrary initial solution. The following difficulties were encountered and solved:

1. The sharp corner of the base created a singularity that caused unrealistic pressures and stopped the computation. This problem was solved by extending the computational region upstream of the corner.
2. A forward-moving jet developed at the outflow (downstream) boundary of the computational region. The resulting "departure" solution did not converge. This problem was solved by extending the computational region downstream much farther than indicated by the experiment (see next item).
3. The developing flowfield of the time-marched numerical simulation is much longer than the experimentally observed one (the rear stagnation point is farther away from the base). An increase in grid resolution near the longitudinal axis brought the stagnation point closer to the experimental location (about one base diameter). However, there are still numerically generated ripples in the density and velocity profiles near the axis. These numerical problems are related to the artificial smoothing used in the computational algorithm. An analysis of the smoothing is underway to resolve this problem.

At this time the base flow solution is not completely converged, but it is qualitatively correct. Figure 1 shows a velocity vector plot of the base flow simulation, with the characteristic pattern of recirculating flow. Figure 2 shows computed density profiles at various stations downstream of the base, and the corresponding plot of experimental results from Blankson and Finston (1975). As can be seen in the figure, the structure of the computed flowfield follows closely the experimental results. Quantitative comparisons will be made when a converged computation is achieved.

REFERENCES

- Blankson, I.M., and Finston, M. (1975) "Measurements in the Laminar Near-Wake of Magnetically Suspended Cones at $M=6.3$ ", AIAA Journal, Vol. 13, No. 11, December 1975.



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Fig. 1 Velocity vector plot of the simulated base flow for M=6.3, Re=86,000

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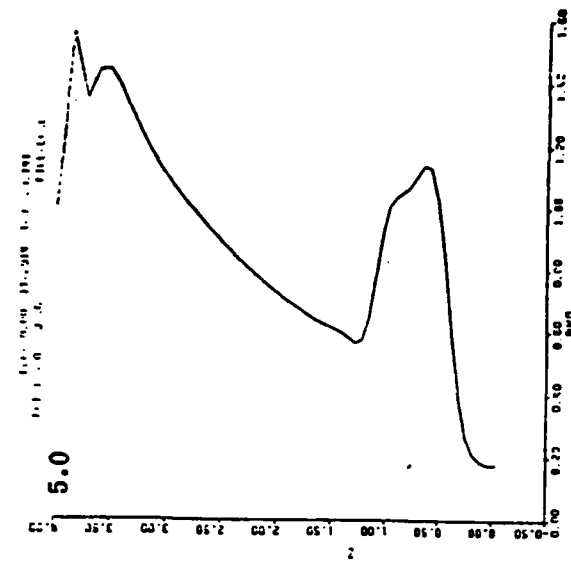
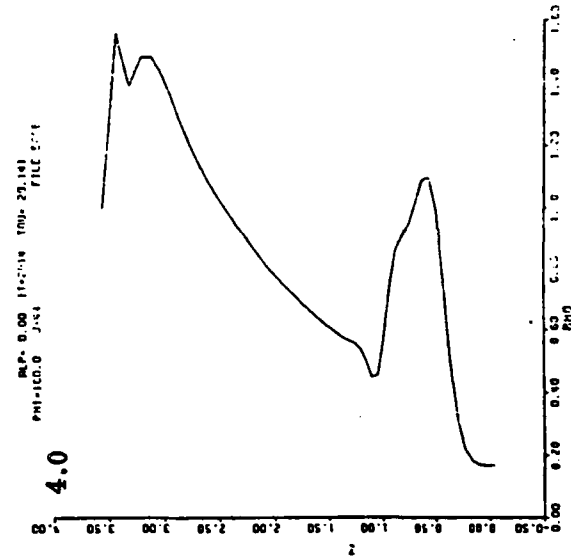
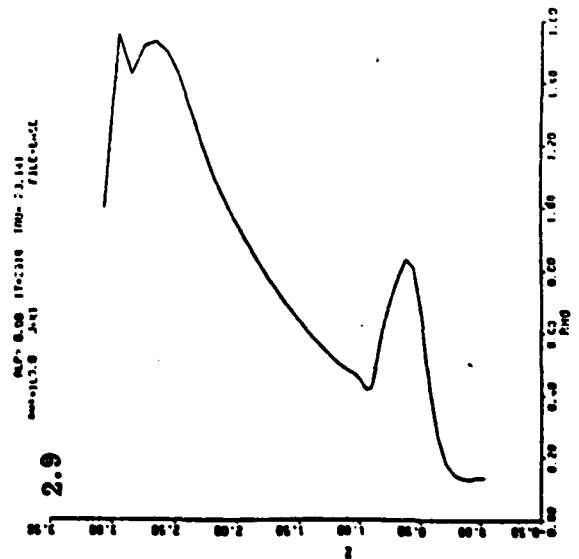
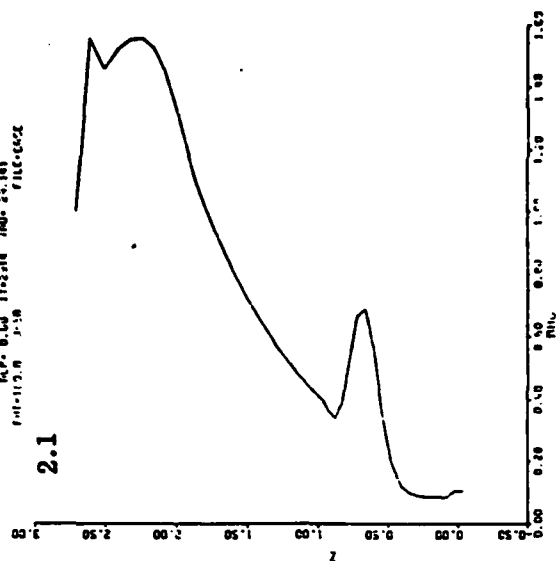
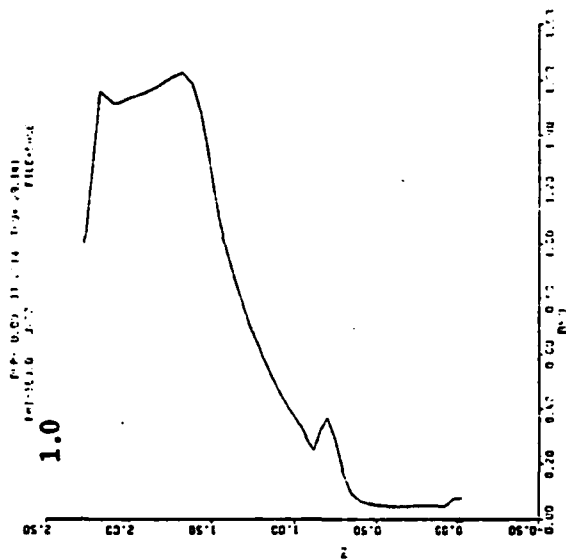
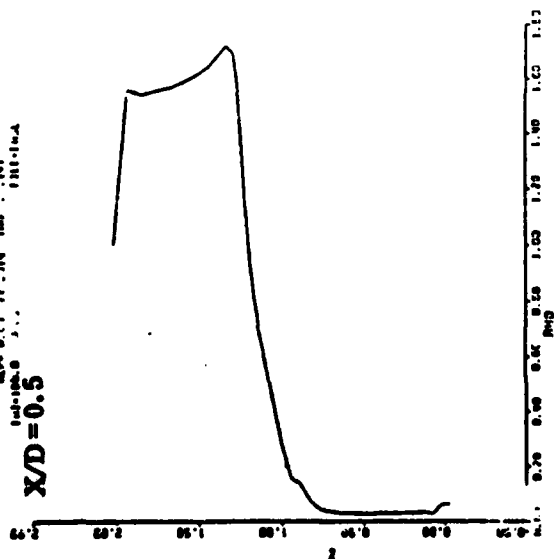
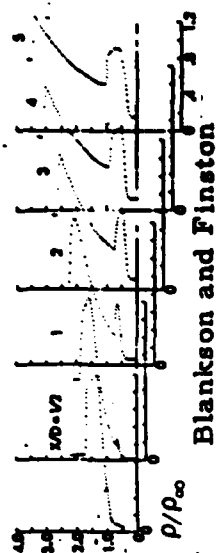


Fig. 2 Computed density profiles at various stations downstream of the base